1.2.1. STUDY OF MOST USED MATERIALS IN CONSTRUCTION SECTOR IN SPAIN.

OERCO2

ONLINE EDUCATIONAL RESOURCE FOR INNOVATIVE STUDY OF CONSTRUCTION MATERIALS LIFE CYCLE

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1. Introduction

In the last few years, sustainability has gained great importance in the awareness of society due to the need to protect the environment on the basis of managing sustainable development. Accordingly, construction of more sustainable buildings acquires a role protagonist in the current picture. Aspects such as energy efficiency and natural resource consumption, as well as the reuse of them and product and buildings life cycle management are investigated in many research studies.

This increasing interest for the sustainability has been attributable to the strong activity that construction sector has experienced and it has caused an environmental deterioration through excessive natural resources consumption, the massive amounts of energy required to produce construction products or impact produced by uncontrolled dumping of construction or demolition wastes (RCD) in illegal sites, without prior control or treatment (Adnan et al., 2014).

To correct this situation, laws and plans are developed at international, Europe and local level, those promote sustainability, recycling and reuse (Marrero et al. 2011). At European level, European Waste Framework Directive has formulated to prevention and RCD reuse (European Parliament and Council, 2009). However, managements models implemented are still far from reaching their targets, to get the recycling 70% of the RCD generated in Europe by 2020, because the reality of the situation shows that only 50% are recycled (Soniego et al., 2010).

In Spain, Royal Decree 105/2008 was adopted (Ministry of the Presidency, 2008), the purpose of which is to establish the legal regime of production and management of RCD, to their prevention, reuse and recycling. On the other hand, the latest legislative requirements for energy efficiency in Spain, as Royal Decree on the energy certification RD 235/2013 (Ministry of the Presidency, 2013), and The Law 8/2013 (Head of State, 2013), establish the regulation of basic requirements for buildings with regards to sustainable rehabilitation. That is the equivalent to an increase of rehabilitation and demolition works, entailing an increase in RCD generated which must be managed correctly.

We are now facing the problems derived from construction activity, as well as state and European new regulations whose advocate for energetic efficiency and sustainability, must be found new methods to lower the impact caused by construction on the environment (Andreola et al. 2005) (Lett, 2014) (Schaffartzik et al. 2014) (Haas et al. 2015).

The research in this line of work, among other aspects, is through try to minimize environmental impact, greenhouse gas emissions or consumption of material resources, improve the energy efficiency or rehabilitation at individual or local level. Accordingly, numerous investigations specify that materials of construction are the responsible a large extend for environmental impact resulting from the construction: involve from the beginning until the end of the constructive process. With their appropriate choice can shift towards better environmental performance (Andr et al. 2016).

2. Evaluation of the materials and operational solutions most used in construction

Depart from researchers' previous studies of the University of Sevilla, it has become evident, at Spanish state level: the most used residential typologies, the most used materials and the most common constructive solutions.

The studies employed can also be asked in the three following publications:

- Martínez Rocamora, Alejandro, Solís Guzmán, Jaime, Marrero Meléndez, Madelyn:LCA databasesfocusedonconstructionmaterials: A review. En: Renewable and SustainableEnergyReviews. 2016. Vol. 58. Pag. 565-573.
- González Vallejo, Patricia, Solís Guzmán, Jaime, Llácer Pantión, Rafael, Marrero Meléndez, Madelyn:La construcción de edificios residenciales en España en el período 2007-2010 y su impacto según el indicador Huella Ecológica. En: Informes de la Construcción. 2015. Vol. 67. Núm. 539.
- González Vallejo, Patricia, Marrero Meléndez, Madelyn, Solís Guzmán, Jaime:The ecologicalfootprint of dwellingconstruction in Spain. En: EcologicalIndicators. 2015. Núm. 52. Pag. 75-84.

The first analysis falls to the typologies of residential buildings, in the table 1.

Number of floors		Year							
		2007		2008		2009		2010	
		Total	%	Total	%	Total	%	Total	%
Over level floors	0 y 1	23.572	4	14.042	5	7.759	6	7.479	8
	2	151.902	24	63.913	24	27.668	21	24.101	26
	3	144.723	23	52.694	20	25.014	19	13.631	15
	4 y 5	210.065	33	86.744	32	38.515	30	25.661	28
	6 or more	103.836	16	51.042	19	31.590	24	20.773	23
	TOTAL	**634098**	**100**	**268435**	**100**	**130546**	**100**	**91645**	**100**
Under level floors	0	141.777	22	66.840	22	30.507	23	25.216	28
	1	328.920	52	121.018	52	59.321	45	37.288	41
	2 or more	163.401	26	80.577	26	29.141	31	29.141	32
	TOTAL	**634098**	**100**	**268435**	**100**	**118969**	**100**	**91645**	**100**

Table 1: Number of homes built in Spain according number of floors over and under levels (2007-2010).

Residential new buildings have been studied because in the last decade represented in Spain around 80% of the total built area. From the characteristics set out highlight for this analysis the great number of floors over and under levels, since that characteristic defines largely the constructive solutions, being a key determinant for the evaluation for the environmental impact of each of the buildings. A greater percentage of buildings are identified between 4 and 5 floors over level and least representative are buildings with 0 or 1 floors.

Also, to stress those multifamily houses (2 or more homes) represent 75% and family homes the rest 25%. According to the number of floors over level, the 6% have only one floor, 24% two, split between family and multifamily houses.

The second part of the study corresponds to the analysis of constructive solutions. Are illustrated the percentages of new buildings with residential use according to constructive typology, installations and interior layout, concerning each year from 2007 to 2010, as ever year present similar dates, have been represented the mean values in the Table 2.

Constructive characteristics of residential building (%)							
Vertical structure				**Horizontal structure**		**Roof**	
Reinforced concrete	**Metal**	**Load bearing wall**	**Mixed and others**	**Unidirec.**	**Slab**	**Flat**	**Sloping**
73	6	15	6	84	16	33	67
Building envelope				**Exterior woodwork**			
Ceramic	**Stone**	**Continuous lining**	**Others**	**Wood**	**Alum.**	**Plastic**	**Steel sheet and others**
50	12	34	4	8	84	7	1
Installations							
Waste-water disposal	**Drinking water provision**	**Hot water**	**Heat**	**Cooling**	**Elevators and/or lifts**	**Waste-water treatments**	**Other resources treatments**
100	100	96	65	18	68	7	2
Internal finishes							
Floor				**Interior woodwork**		**With false ceiling**	**With blinds**
Ceramic	**Stone**	**Wood**	**Others**	**Wood**	**Others**		
53	15	29	3	98	2	76	93

Table 2: Percentage of new buildings with residential use according to constructive characteristics.

From de results, it can be prominent two characteristics that are common in all the typologies:

- Exterior woodwork is made aluminium.
- Interior woodwork is made of wood and blinds.

Finally, from the detailed study of many projects and evaluating their material consumptions can be determinate the most employed materials in the construction of residential buildings in Spain.

So, from these studies was obtained that more presence material in Spanish building, because of their percentage in weight or because their high environmental impact, are the following:

- Concrete: represents more than 50% by weight of employed in construction materials.

- Ceramics: Spanish construction is intensive in brick, ceramic tiles and material. Percentage in weight according to 10-15% by the total material used in residential building constructions in Spain.
- Steel: little relevance in weight but high incidence in environmental impact (10-20%).
- Aluminium: high energetic consumption, although recycling material, frequently used in Spain, have a lower environmental incidence. We can assume that the average aluminium production is about 30% of recycled material. Low weight.
- Polystyrene: plastic material commonly used as insulation material. Relatively easy recycling, that permits to obtain new blocks with 50% of recycled material.
- PVC: highly used in buildings plastic material Similar environmental impact as polystyrene.

From these six materials, five of them (concrete, Steel, ceramics, polystyrene and PVC) approximately represent the 80% of environmental impact generated by materials in building construction in Spain.

From stages of the work, these with highest environmental incidence are: structures, brickwork, coatings and foundations.

Analysing these four chapters, for the foundations case the material with highest impact generated in that phase are concrete and steel fibre of reinforce bars. In the case of structures cases, the highest impact materials are steel fibre of reinforce bars, cement of bricks and reinforced concrete, in that order. For brickwork chapter, the impact of materials is due to ceramic bricks. Finally, in coating case, the highest impact materials are mass concrete of slabs, ceramic tiles and at last, garnished and coated perlite mortar. In that case impact is generated by intensive use of labour.

3. Evaluation of the materials and sustainable solutions most used in construction

Based on this proposition, the new investigating for new solutions (construction materials and constructive process), alternatives to conventional solutions, those have something to sustainable contributed in constructive process taken up a main role to solve problems by construction sector.

There are some products and constructive systems those income their incorporation into the building design, help to improve its sustainable.

At first, wood, for years, has been proposed as natural material with lower environmental impact generated for its life cycle, being necessary its certification to verify its production process and its sustainable origin. However, the high quantities of energy needed to their processing and drying, made environmental benefits not clear.

Other material postulated as natural sustainable material, timber-related trade, is bamboo. This is an under-utilised resource available for developing countries' economies. Bamboo is not easily found in Spain. It is a sturdy, lightweight and mouldable material that is renewed rapidly making its collection does not cause deforestation (Dixon et al., 2015).

On the other hand, there are researches about new constructive products much more complex related to chemical reactions or aggregates compounds to improve their qualities. Between these, photocatalitics mortars currently notable for their incipient employment on construction sites, which are chemically reacted when receive direct sunlight, and absorb the CO_2.

However, one of the sustainable materials group which has gained importance in sustainable construction world those based on the use of construction and demolition wastes (Pozo et al. 2011), through previous management of them (Garz, 2015) (Garzón & Sánchez-Soto, 2013). The management and reuse of wastes are key to face the construction sector problem: reduce production, reuse and recycling (Marrero et al., 2011).

This importance acquired due to data obtained about impact problem by RCD generated. At global level, construction produces around 35% of industrial waste (Hendriks&Pietersen, 2000) (Mercader-Moyano, 2012), reaching 42 million tonnes per year to be placed the majority of these in landfill sites, without minimum approach about their possible reusing (Valdés et al., 2010). In total, there has been an average of 890 million tonnes of RCD in 2008 (Sáez Villoriaet al., 2011), while the recuperation percentage is only 25% (EuropeanEnvironmental Agency (EEA), 2002). At European level, construction activity consumes 40% of natural resources to the construction materials manufacture (EuropeanCommission, 2013) (López-Mesa, 2009).

The new construction materials developing whose employees recycled aggregates from construction wastes (Sousa et al. 2003) a decrease stressing of thermal conductivity are key to work in improved energy efficiency and therefore save energy (Papadopoulos, 2005) (Martínez-Molina et al. 2016).

Furthermore, following with the vein to use recycled wastes aggregates are under researches those develop construction products like blocks, panels and mortars with tires, wood rests, cork or polymeric fibres.

Following Table 3 shows the relationship between researches that develop construction products to try to improve building sustainability through their used and pretends serve as sing of present situation.

AUTHORS	Material/constructive solution	Results
(Jamekhorshid, Sadrameli, Barzin, & Farid, 2017)	Wood-plastic composites with phase changing microencapsulated of PCM (MEPCM)	Energy storage. Improved energy efficiency.
("Available on: http://www.redalyc.org/articulo.oa?id=181320674011," 2008)	Bamboo in natural state. Bamboo press boards or without lineshafts.	Improved sustainability.
(Gramineae, 2016)	House completely performed with bamboo as construction material	House completely performed with bamboo as construction material that meet normative requirements posted in countries of origin
(Teixeira, Bastos, & Almeida, 2015) (Shah, Bock, Mulligan, & Ramage, 2016) (Shah et al., 2016) (Luna, Lizarazo-Marriaga, & Mariño, 2016)	Laminated sheets/bamboo composite	Sufficient resistant and thinnest thickness
(Morales-conde, Rodríguez-liñán, & Pedreño-rojas, 2016)	Gypsum composite and Wood aggregates from demolition of rehabilitant works	Improved composite thermal properties. Decrease of mechanical resistance.
(Başpınar, M. S., & Kahraman, 2011)	Gypsum with mica or vermiculite aggregates	
(del Río Merino, M., García, C. P., & Piñeiro, 2013)	Plaster reinforced with mineral fibres of RCD	
(Jamshidi, Kurumisawa, Nawa, & Igarashi, 2016)	Structural concrete and paving blocks with glass wastes incorporated.	Glass wastes addition improved the life cycle, durability and structural behaviour of the product.
(R. De, De, & De, 2015)	Hydraulic mortars using recycled plastic bottles	Improved fire performance and sustainability
(Marrero, Martínez-Escobar, Mercader-Moyano, & Leiva, 2013)	Panels incorporating gypsum panels and recycled concrete	Minimisation of environmental impact in the implementation of facades. Same mechanical benefits that natural resources realized.
(Meijide, 2015)	Cold bituminous mixtures with RCD aggregates	
(Bedoya & Dzul, 2015)	Structural concrete with recycled aggregates	
(Costa Del Pozo, 2012)	Blocks from recycled plastics (EPS included) and cements	
(Aliabdo, Abd-Elmoaty, & Hassan, 2014)(Miličević, Bjegović, & Siddique, 2015)(Sadek, 2012)	Bricks with recycled aggregates from brick dust and clay roofing tiles	Improved thermal resistance, lower weight and cost, meet normative requirements posted in countries of origin, although that implies visible reduction of block compression resistance and increase water absorption
(Valdés et al., 2010)	Concretes incorporating RCD and cement	Pretend be employed substitute for conventional structural concrete
(González Madariaga & Lloveras Macia, 2008)	Gypsum or plaster panels including EPS recycled	
(Poon & Chan, 2006)(Wattanasiriwech, Saiton, & Wattanasiriwech, 2009)	Cobblestones including ceramic crushed materials	Major water absorption than similar products on the market.
(Alba, Marrero, Leiva, Montes, & Vilches, 2012)	Panels made with fly ashes from thermal centrals and cement	
(del Río Merino, M. R., Astorqui, J. S. C., & Olivares, 2005) (del Río Merino, M., Hernández Olivares, F., & Comino Almenara, 2004)	Plaster reinforced with glass fibres	
(Cherki, A. B., Remy, B., Khabbazi, A., Jannot, Y., & Baillis, 2014)	Gypsum with lighten cork aggregates	
(De Melo & Silva, 2013)	Non-structural concrete blocks including EVA wastes (shoes)	
(del Río Merino, M., Domínguez, J. D., & Hernández Olivares, 1998)	Plaster lightened with cellular solids: expanded clay	
(Machado & Pereira, 2016)	Cork composites	Improved energy efficiency

(Concepción & Menor, 2015)	Structural concrete and concrete blocks with cork aggregates	Lightened parts. Decrease in thermal conductivity.
(Serna, Á., del Río, M., Palomo, J. G., & González, 2012)(Parres, F., Crespo-Amorós, J. E., & Nadal-Gisbert, 2009)	Reinforced plaster with aggregates of crushed tires	
(Aguilera, 2013) ("197-708-1-PB.pdf," n.d.)	Plaster with aggregates of crushed rice husk residues	
(Ingeniari, Nekazaritza, Abeltzaintza, & Berezitasuna, 2011)	Brick that uses marginal soil instead of cooked clay	No cooking is required. Improving sustainability
(Gatani, 2000)	Bricks of compact earth and cement	Increased humidity compared to traditional ones
(Sustentable, De, Patricia, & Sánchez, 2015)	Compressed earth blocks	
(Ruan & Unluer, 2016)	Cement with magnesium aggregates (MgO)	Minimisation of reactive energy needed in Portland cements
(Edificaci, 2016)	Photocatalytic materials: mortars	Decrease in environmental impact
(Sugr, n.d.)	Mortars with self-cleaning and decontaminating properties	Decrease in environmental impact
(R. F. De, 2016)	Sheep wool as insulation material	
(Baglivo & Congedo, 2016)	Lightweight multilayer composite walls	High level of thermal performance and interior comfort
(Assefa & Ambler, 2017)	Use of a trombe wall	Improving energy efficiency
(Neila, Bedoya, Acha, Olivieri, & Barbero, 2008)	Ecological roof	

Table 3: Use of sustainable materials in current literature

Regarding to the private sector, numerous commercial houses appear that commercialize products that improve the sustainability. Next, it establishes a list of companies and their related construction products and systems whose environmental behaviour has been verified by EPD, Environmental Product Declarations. The difference between the number of research works, and the variety of solutions and use of raw materials on these types of products and those marketed (Table 4).

COMPANY	Material/constructive solution
Favemanc. Toledo	Medium ceramic plate for ventilated facade: internal chamber that strengthens them by increasing the thermal and acoustic insulation of the building.
Rosa Gres, S.A. Barcelona	Dry pressed ceramic tile composed of clay, feldspar and sand with a coating of enamel.
Porcelanosa. Castellón	Medium tile composed of clay, carbonate, sand, feldspar with a coating of enamel.
COLORKER S.A. Castellón	Glazed/Porcelain stoneware made of clay, feldspar and sand with a coating of enamel
KnaufInsulation, SL SantBoi de Llobregat	Panel Plus is a thermos-acoustic insulation of Natural Mineral Wool with uniform texture, which is presented in the form of semi-rigid nude panels.
BASF ESPAÑOLA, S.L. Rubí	Special fire retardant rigid polysocyanurate foam (PIR) system
Porcelanosa Grupo. Castellón	Porcelanosa porcelain stoneware is composed mainly of clay, sand, feldspar with a coating of enamel composed mainly of feldspar, carbonate, silicates and kaolin among others.
KnaufInsulation, SL SantBoi de Llobregat	Uncoated panel is a thermos-acoustic insulation of Natural Mineral Wool with uniform texture, which is presented in the form of bare panels.
BASF ESPAÑOLA, S.L. Rubí	Itracoustic R is a thermos-acoustic insulation in compact roll panels of Natural Mineral Wool. They are characterised by their porous structure that strongly retains air in their interior and by the size and diameter of their filaments, in addition to their elasticity.

Federación Nacional de la Pizarra. Orense	Medium natural slate representative of the Spanish slate sector and which includes different formats of slate.
Fundación Centro Tecnolóxico do Granito de Galicia. Porriño	Exterior granite flooring.
Fundación Centro Tecnolóxico do Granito de Galicia. Porriño	Glazed for ventilated granite facade.
Grespania, S.A. Castellón	Medium porcelain stoneware.
Grespania, S.A. Castellón	BIONICTILE®, a porcelain stoneware (Bla) with photocatalytic activity.
BASF Construction Chemicals España, S.L. L'Hospitalet de Llobregat	Solvent-free two-component epoxy primer for use in young concrete or mortar with high residual moisture content. Two-component epoxy primer free of fast curing solvents and low temperature application. Solvent-free two-component epoxy primer for synthetic coatings on mineral substrates. Elastic and self-levelling coating of bicomponent polyurethane for comfortable and decorative floors. Solvent-free, self-levelling, elastic, pigmented and low-emission two-component polyurethane coating. UV-resistant, self-levelling, elastic, pigmented, low emission, polyurethane, solvent-free polyurethane coating for decorative flooring. Water-based, solvent-free, low-emission polyurethane finish coating in AbgBB, elastic, matte, pigmented or transparent, constant colour and resistant to UV rays for comfortable and decorative flooring.
BASF Construction Chemicals España, S.L. L'Hospitalet de Llobregat	Self-levelling epoxy coating solvent-free and very low emissions (according to AgBB) for the realisation of pavements.

Table 4: Use of sustainable materials in companies

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